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Rottnest Island artifacts and palaeosols in the context of Greater Swan Region prehistory

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Abstract

The prehistoric record of Rottnest island 19 km offshore the Swan Region, Western Australia, consists solely of three stone artifacts. Two are Eocene fossiliferous chert flakes probably deriving from palaeosols in the Tamala Limestone cliffs at Fish Hook Bay and Little Armstrong Bay. A third is a calcrete flake from a siliceous dune blow-out near Fish Hook Bay. A feldspar pebble *in situ* in a palaeosol intercalated between aeolian calcarenite units at City of York Bay is probably a manuport. The age of the Little Armstrong Bay and City of York Bay palaeosols is estimated to be 15,000 to 50,000 years old. Similarities in pedology and in stratigraphic position suggest that these two palaeosols belong to a single palaeosol unit extending along Rottnest Island's northern shore, a possibility that could give scope to further prehistoric investigations on the island. Prehistoric remains could also be *in situ* in palaeosols and sandy sediments infilling solution pipes and other Tamala Limestone features on the island's littoral and submerged offshore. Of possible archaeological significance are two charcoal concentrations and a pit- like feature *in situ* in the lowermost palaeosol unit in the aeolian calcarenite cliffs at Fish Hook Bay. Charcoal from one concentration is radiocarbon dated *ca.* 18,600 yr b.p. A *Turbo* shell sample from a storm beach deposit emplaced in a wave-cut notch 3.4 m above sea level in the Fish Hook Bay palaeosol is radiocarbon dated *ca.* 5700 yr b.p. The former date is probably erroneous, and the palaeosol is estimated to be 40,000 to 80,000 years old. Factors that could account for the dearth of prehistoric evidence on Rottnest Island are: (1) the island's position near the seaward edge of the emergent continental shelf, which was probably less suitable for human occupation than the shelf's more inland parts; (2) site destruction on the island littoral during the Early to Middle Holocene period of rising and high sea level, when the island was 40% larger in area than now; (3) poor surface visibility on the present-day island. The island's minimal prehistoric record is evidence that it was not occupied extensively prior to its formation; its distance offshore implies that it was not visited by Late Holocene Aboriginal sea voyagers. Palaeoenvironmental and archaeological site distributional data from the emergent continental shelf are used in the appraisal of pre-transgression terrestrial environments and prehistoric occupation in the Rottnest locality and elsewhere in the Greater Swan Region. The Rottnest sites appear to be some of the oldest in the region, and suggest the archaeological potential of Tamala Limestone palaeosols.

Introduction

Rottnest Island, 19 km offshore the Swan Region in south-western Western Australia, was separated from the mainland by glacio-eustatic sea level rise about 6500 years ago (Fig 1; Playford 1983, 1988). The 1900 ha limestone island's prehistoric record consists solely of three stone flakes, two collected in 1984 and the third in 1992, and two pebbles (Table 1). These artifacts are the result of many, mostly unsystematic, searches by numerous archaeologists and other Quaternary investigators since the 1960's. Two of these flakes, and another more problematical specimen, a feldspar pebble also collected in 1992, suggest the archaeological potential of the palaeosol horizons intercalated with the aeolian calcarenite units comprising the greater part of the Tamala Limestone (formerly Coastal Limestone), which is the constituent rock of Rottnest Island, and one of the main Quaternary units in the Perth Basin (Playford 1983; 1988; Playford *et al.* 1976).

The two 1992 finds and the palaeosols at their find spots are described below, along with another recently recorded palaeosol that may be of archaeological significance. We also examine some of the factors that could account for Rottnest Island's extraordinarily sparse prehistoric remains, assess the archaeological potential of the island's littoral and offshore environs, and review palaeoenvironmental data that give insight into the suitability of the Rottnest area for human occupation prior to post-glacial marine transgression.

Fundamental to this assessment of Rottnest island prehistory is the premise that the submerged continental shelf west of the lower reaches of the Swan estuary and environs (Fig 1) is an integral part of the "Greater Swan Region" - an informal term referring to the exposed shelf

Table 1
Summary of 1984 and 1992 Rottnest Island prehistoric stone artifacts and other finds

Specimen	Find spot	WA Museum Accession No.	Aboriginal Sites Dept Reg. No.
1984			
Eocene chert flake	Fish Hook Bay	B5612	S02099
Calcrete flake	Fish Hook Bay, East	B3123	S02099
1992			
Feldspar pebble	City of York Bay	B7712	S02276
Eocene chert flake	Little Armstrong Bay	B7713	S02275
Quartzite pebble	Little Armstrong Bay	B7746	S02275

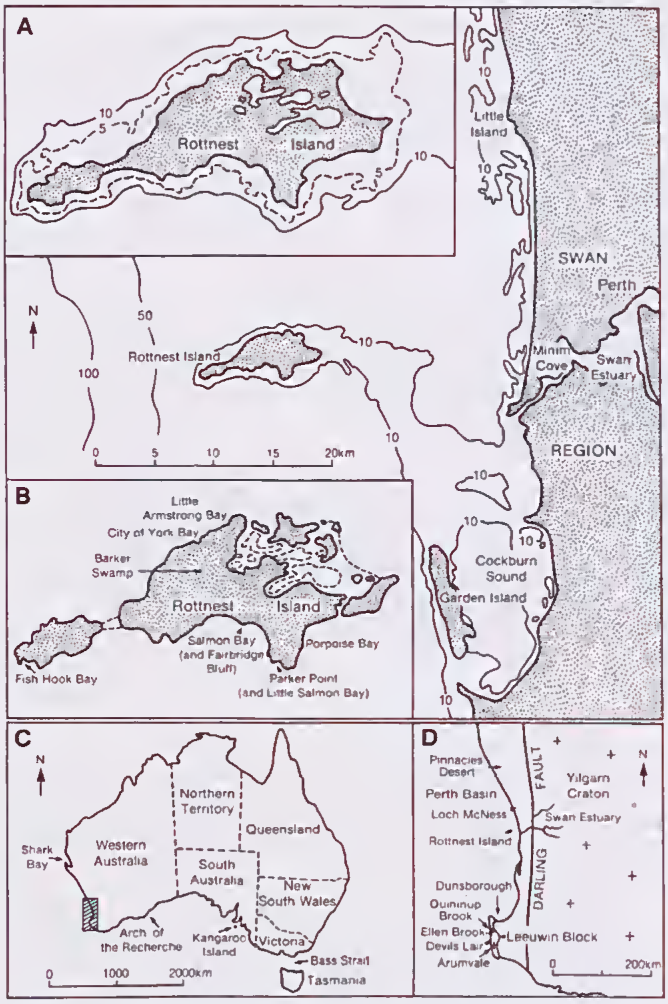


Figure 1. Rottnest island and the Greater Swan Region, Western Australia, showing the 10, 50 and 100 m bathymetric depth contours. Inset A: Rottnest Island showing salt lakes. Island size *ca.* 6500 yr b.p. is based on 5 m depth contour (stippled line). The zone between the 5 and 10 m contours (solid line) indicates approximate land area just before island formation (after Department of Marine and Harbours, WA 1988). Inset B: Rottnest Island at maximum inundation during the Middle Holocene. Modern shoreline and salt lakes indicated by stippled lines (after Playford 1988). Insets C and D: Locality maps.

area accessible to hunter-gatherer populations during the glacio-eustatic low sea levels that persisted through the late Pleistocene and Early Holocene (Chappell & Shackleton 1986, Thom & Chappell 1975). This region extends westward from the Darling Fault scarp through the Swan riverine/ estuarine drainage basin to the steepening edge of the continental shelf 10 km west of Rottnest Island, demarcated by the 50 and 100 m depth contours (Fig 1).

Archaeological assessment of pre-transgression human occupation on this and other parts of the submerged shelf off the Indian Ocean coast of southwestern Australia is enhanced by the record of numerous Eocene fossiliferous chert artifact assemblages distributed throughout the emergent Perth Basin and Leeuwin Block (Fig 1D; Glover 1984). Interpreted as deriving from a "concealed western provenance", *i.e.* quarry-factories centred on chert outcrops totally or mostly submerged by glacio-eustatic sea level rise (Glover & Lee 1984), these onshore chert assemblages comprise "the most extensive material record in Australia directly relating to human activities [minimally chert quarrying and knapping] on the now-submerged continental shelves" (Dortch 1991).

Survey aims and methods

Rottnest Island consists mostly of aeolian calcarenite, that is generally covered by heath- vegetated dunes (Hesp *et al.* 1983, Playford 1983, 1988); the salt lakes cover approximately 10 % of the island's area (Fig 1A). Survey for prehistoric sites on the island, mainly carried out by one of us (CED) for the WA Museum, has been largely confined to eroded areas on or near Tamala Limestone coastal cliffs and headlands. These features are important in the survey because intercalated with the aeolian calcarenite units forming these cliffs are calcareous palaeosols which could yield prehistoric occupation material, as was suggested by the provenance and surface condition of an Eocene fossiliferous chert flake found on the island in 1984 (see below). The primary survey aim in 1992 was to test the hypothesis that Rottnest Island palaeosols, occurring within the Tamala Limestone and dating to the Late Pleistocene, contained stone artifacts or other prehistoric remains.

The survey has closely covered an estimated 50% of the palaeosols exposed on the summits and in the faces of the island's coastal cliffs and headlands, and perhaps 30% of the eroded areas of aeolian calcarenite and palaeosol remnants in the island's interior, particularly those near the salt lakes (Fig 1A). Survey of the smaller areas of siliceous dune blow-outs, that are residual from the weathering of the aeolian calcarenite (Playford 1988: 22), has not been extensive, with at most 20 % of these features having been searched. Very little survey has been carried out in dense heath, in the extant patches of native low forest, or in the much larger areas of tree plantation. Underwater survey of Tamala Limestone features submerged offshore has been done around Parker Point, in Fish Hook Bay and in Little Armstrong Bay (Fig 1B).

The archaeological survey has been concerned solely with locating and recording individual small finds or features relating to prehistoric occupation prior to Rottnest's formation because, as discussed below, it is improbable that the island was later reached by mid-late Holocene prehistoric voyagers from the mainland. Survey has not been orientated toward terrestrial habitats on the island that would seem likely to have invited prehistoric occupation. This is because the present-day island is a scant and heavily eroded remnant of a vast area of emergent continental shelf that was exploited by prehistoric populations in ways that are conjectural, and because the locality's pre-transgression terrestrial habitats probably differed significantly from those existing at the time of European discovery (Backhouse 1993, Storr *et al.* 1959).

Rottnest prehistoric finds and their provenances

The 1984 finds

One of the two stone artifacts found on Rottnest in 1984 is an Eocene fossiliferous chert flake (Fig 2:1) collected from "limestone rubble exposed by the deflation of one or more dune soils" (Dortch & Morse 1984) on an eroding Tamala Limestone cliff-top overlooking Fish Hook Bay (Fig 1B). It is significant that this flake's surfaces (ventral/dorsal faces and butt) are semi-lustrous and only slightly weathered, showing that it has not been subjected long to open-air conditions. The second 1984 find, a deeply weathered calcrete flake (Fig 2:2; Dortch 1991), is from a siliceous dune blow-out on the limestone cliff summit about 300 m east of this bay.

The 1992 finds

The smaller end of the feldspar pebble from City of York Bay (Fig 2:3) has a fracture surface along a cleavage plane that was broken after the stone was rounded; no archaeological significance is attributed to this fracture. The nearest known sources of feldspar pebbles deriving from the Yilgarn Craton are mainland alluvial gravels in the vicinity of the Darling Fault, 50 km east of Rottnest Island (Fig 1D). This feldspar pebble (weight 12.41 g, maximum length 33 mm) is in the size range of emu crop stones (pers. comm.: R Johnstone, Department of Terrestrial Vertebrates, WA Museum). However, the considerable distance between Rottnest Island and the nearest known feldspar sources, and this pebble's relatively large size suggest to us that it is more likely to be a manuport (*i.e.* an object transported through human agency) than a crop stone.

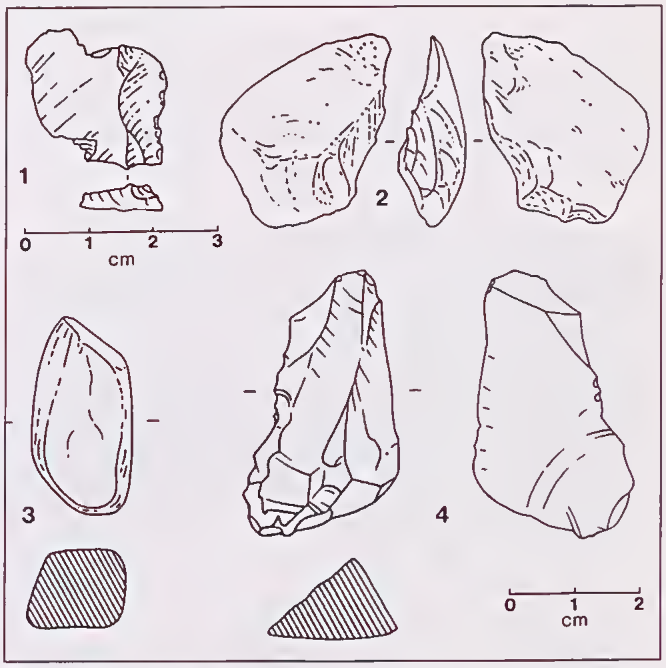


Figure 2. Prehistoric finds from Rottnest Island. 1984 specimens: **1** Eocene fossiliferous chert flake from Fish Hook Bay; **2** calcrete flake from 300 m East of Fish Hook Bay. 1992 specimens: **3** feldspar pebble from City of York Bay; **4** Eocene fossiliferous chert flake from Little Armstrong Bay.

The Eocene fossiliferous chert flake from Little Armstrong Bay (Fig 2:4) weighs 6.98 g, and has a maximum length of 44 mm. It has a diffuse bulb of percussion and a linear butt, features characteristic of bipolar percussion. The two prominent flake scars covering the dorsal face have been produced by blows against its distal end, probably by means of counter-percussion, as suggested by the very small flake scar facets and crushing that have removed the proximal ends of the prominent flake scars. The flake has a prominent notch midway along its left edge' produced deliberately by three or more blows. The flake's surface is uniformly matt, finely porous, and light-hued, whitish-buff, similar to the colour of the sandy palaeosol from which it probably derives (see below). Like the 1984 chert flake (Fig 2:1), the 1992 flake " ... appears to have been buried in a stable deposit for most of the time since it was discarded" (Dortch & Morse 1984).

A weathered quartzite pebble (Table 1: B7746) was collected *in situ* in the palaeosol at Little Armstrong Bay 1 m east of the chert flake's find spot. This piece is conceivably a manuport, although its very small size (weight 1.26 g; maximum dimension 16 mm) suggests that it was naturally transported; for example, it could be a bird crop stone.

The City of York Bay and Little Armstrong Bay find sites

The two 1992 prehistoric finds are from aeolian calcarenite cliffs at City of York Bay, and at Little Armstrong Bay, 1100 m further north-eastward along the northern shore of the island (Fig 1, Table 1). Each cliff face features a prominent palaeosol intercalated between aeolian calcarenite units. The feldspar pebble was found *in situ* in the City of York Bay palaeosol (Fig 3a). The chert flake from Little Armstrong Bay, however, was not *in situ*, but found lying on a 10 cm-thick deposit of fine carbonate sand covering a calcarenite ledge at the foot of the prominent palaeosol exposed in a 1 to 1.3 m-high section in this cliff face (Fig 3b). This sand closely resembles that in the palaeosol, and almost certainly is eroded from the palaeosol section, as is the case with the chert flake. Less likely derivations for the flake are the summit of the cliff, or the aeolian calcarenite unit forming a 1 m-wide overhang above the palaeosol section. Sieving of

Figure 3. Tamala Limestone cliffs on Rottnest Island, showing cross-bedded aeoline calcarenite palaeosols: **TOP** City of York Bay, the position of the feldspar pebble (Fig 2: 3) found *in situ* is in the shaded area beneath the calcarenite overhang; **BOTTOM** Little Armstrong Bay, 15 cm scale in centre of palaeosol section.

approximately 100 litres of the loose sand on which the flake was lying yielded no archaeological finds, but did reveal small calcareous nodules, rhizotubules and land snail shells (*Austrosuccinea* sp.), as found in the palaeosol.

The palaeosols at both these find spots display moderately deep (*ca.* 0.6 m), light-grey A horizons with diffuse contacts to a lower C horizon; no B horizon is present. The A and C horizons in the Little Armstrong Bay palaeosol are formed in fine carbonate sand, with very small fraction of fine-medium quartz grains dispersed throughout. The City of York Bay palaeosol has an A horizon that is 60% fine carbonate sand and 40% fine-medium quartz sand; its C horizon consists of equal amounts of fine-medium carbonate sand and medium-coarse, well-rounded quartz grains. In both palaeosols, small carbonate nodules and rhizotubules (maximum dimension - 1 cm) are present in frequencies estimated at 100 per 1 m^3. Land snails (*Austrosuccinea* sp.) are common in the upper two thirds of the A horizon of each palaeosol.

The pale cream-white C horizon in each palaeosol appears to be parent material lacking laminae or bedding planes. Observations of presumed Early to Middle Holocene calcareous soils on Rottnest indicate that the C horizon develops via chemical breakdown of the laminated limestone as the A horizon forms. The slightly cemented C horizons have the same colour, texture, and grain size distributions as the underlying, laminated aeolian calcarenite. Limited organic development or leaching takes place in the A horizon presumably due to low rainfall (*ca.* 715 mm p.a.), high exposure, semi-arid vegetation with limited turnover, a Mediterranean climate and limited soil fauna.

The palaeosols at the City of York Bay and Little Armstrong Bay find spots are thus pedogenetically very similar, and their stratigraphic positions within each cliff face, and heights above sea level are also much the same (Table 2; Fig 3a, b). Closely resembling these two soil horizons are ones intercalated with calcarenite units at Charlotte Point and at the east end of Catherine Beach, 300-400 m east of the City of York Bay find spot. The Little Armstrong Bay palaeosol extends eastward along the shore about 300 m, and several palaeosol horizons exposed in coastal cliffs several hundred metres further to the east may be part of this same unit. While we stress that the palaeosols cannot be traced laterally very far, the City of York Bay and Little Armstrong Bay palaeosols appear to belong to a single soil unit extending more than 1500 m along the northern shore of the island. Other exposed palaeosols in the cliffed series of headlands near the western end of the island, 3 to 5 km from City of York Bay, may also belong to this putative soil unit. This is a question of some consequence, since the widespread distribution on the island of a palaeosol having potential for at least rare finds would greatly enhance the chances for discoveries of prehistoric remains.

Estimated age of The City of York Bay and Little Armstrong Bay palaeosols

The City of York Bay and Little Armstrong Bay palaeosols are overlain by thick aeolian calcarenite units. These are truncated and cliffed lee slope and slipface beds, the foreset beds having been removed by wave action. Even if these aeolian units were formed as steep, climbing dunes, it is highly unlikely that they were formed at modern or mid-Holocene sea levels. This is because the dune crests are also absent, and if one projects the crests and windward (foreset) slopes seaward, the toe of the windward slopes would extend below sea level. The dune units were thus formed during Pleistocene lower sea levels when the glacial beach was some distance north and west of Rottnest. The age range for the underlying palaeosols is therefore speculated to be *ca.* 15,000 to 50,000 years old (Chappell & Shackleton 1986; Thom & Chappell 1975). This estimate is further supported by the fact that the overlying aeolian dune units are lithified, whereas younger dunes mantling the Tamala Limestone are poorly lithified or unconsolidated. Many of these younger dunes have steep seaward faces, and appear to have formed during or after the latter stages of post-glacial marine transgression.

Table 2

Physical description of palaeosol horizons at City of York Bay, Little Armstrong Bay and Fish Hook Bay. Elevation is a.s.l. (top of a horizon).

	City of York Bay	Little	Fish Hook Bay
Munsell colour			
A horizon	10 YR 7/2	10 YR 7/2	7.5 YR 5/3
C horizon	10 YR 8/1	5 Y 8/1	5 Y 8/1
grain lithology			
A horizon	carbonate/quartz	carbonate	carbonate
C horizon	carbonate/quartz	carbonate	-
grain size			
A horizon	fine-medium sand	fine sand	fine sand
C horizon	fine-medium-coarse	fine	-
organic content	nil	nil	scattered or concentrated charcoal fragments
A horizon thickness	0.8-1.2 m	0.6 m	2.3 m
elevation	7 m	9 m	4 m

The Fish Hook Bay Site

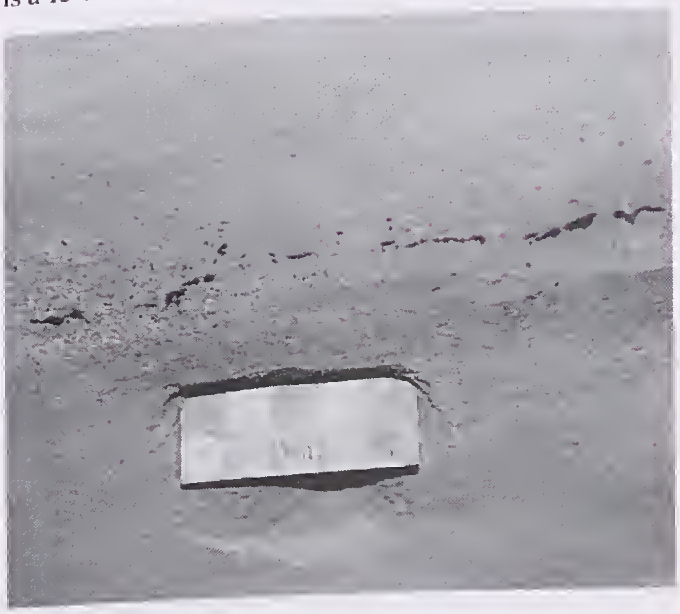
Most of the palaeosol sections exposed in cliff faces along the northern shore of Rottnest Island have been searched for archaeological material, as have many palaeosol sections on the island's southern shore. Apart from the finds listed in Table 1, the only other possible prehistoric remains recorded so far are in a palaeosol section at the base of the 20 to 25 m - high calcarenite cliffs in the eastern corner of Fish Hook Bay (Table 2). No other exposure of this palaeosol, which is at the base of a series of three aeolian calcarenite units intercalated with two other palaeosols, has been identified at this bay or elsewhere on the island.

This lowermost Fish Hook Bay palaeosol is exposed beneath a calcarenite overhang in an eroded section 3.5 m thick; the unit is concealed from view by an 8 m - high mass of huge limestone blocks and scree material fallen from the face of the overlying cliff. A wave-cut notch is formed in the palaeosol at *ca.* 3.4 m above sea level, and its base is being eroded by wave or tidal action to form an active sea cave of unknown length. The south-facing palaeosol is exposed in a 10 m long section. It consists of very slightly cemented fine carbonate sand, and has a very deep (2.3 m) A horizon varying in colour from dark to light brown (mean 7.5 YR 5/3: brown). The soil contains *Leptopius* pupal cases, rare carbonate nodules, and in its uppermost 1 metre *Austrosuccinea* shells. The A horizon has a diffuse boundary with a 1.2 m thick lower 'unit' (tentatively designated as a C horizon) showing intense rhizotubule development.

In the middle of the A horizon are two charcoal concentrations separated by a pit-like structure (Fig 4a). The charcoal concentrations are approximately 70 cm from the top of the A horizon, and about 70 cm apart. Each consists of very friable charcoal fragments 2-15 mm in maximum dimension. The northernmost, best-defined concentration is a horizontal band 65-70 cm long, and about 1 cm thick; the charcoal fragments forming this band are not contiguous but are separated by sand fill, showing that the charcoal and the sand were deposited at the same time (Fig 4b). This charcoal band shows no signs of having been burnt *in situ*, as it has no associated white ash, or fire-crazed and scorched sand grains characteristic of hearths and other fire zones in primary position. The other charcoal concentration is more widely redistributed, and consists of several isolated charcoal fragments forming a horizontally oriented cluster about 30 cm long and 15 cm high. Minute charcoal fragments are present in the palaeosol section above the two charcoal concentrations but not below. Whether the charcoal in these concentrations derives from bush fires, or from hearths or other fires associated with human activities is open to question.

The pit-like structure (Fig 4a) is 50 cm wide at its top, and measures 45 cm from top to bottom. The feature is defined by its fill of dark brown sand, and by a thin carbonate encrustation

Figure 4. Fish Hook Bay palaeosol: **TOP** northernmost charcoal concentration and pit-like structure; **BOTTOM** close-up of charcoal concentration in 4a. In both photographs is a 15 cm scale.



on its right side and a line of very small calcarenite nodules on the other. It could be a burnt tree root or possibly an Aboriginal fire pit. The two charcoal concentrations and the top of this structure are much the same height, suggesting that all three are contemporaneous.

The palaeosol has been notched by wave action subsequent to its formation and to the deposition of the overlying 20-25 m-high aeolian calcarenite cliff. A storm beach deposit, 2.3 m long and 30 cm thick, and comprising small (5-8 cm) to large (30 cm) calcarenite cobbles is emplaced in the palaeosol where the wave-cut notch broadens into a bench at the southern end of the section, approximately 3.4 m above sea level (Fig 5). A few marine mollusc (*Turbo*) shells are *in situ* among the imbricated calcarenite cobbles. The beach deposit is partly buried by collapse of the overlying calcarenite units, which formed a wide overhang above the storm beach and palaeosol, judging by the massive amounts and size of the calcarenite blocks accumulated in front.

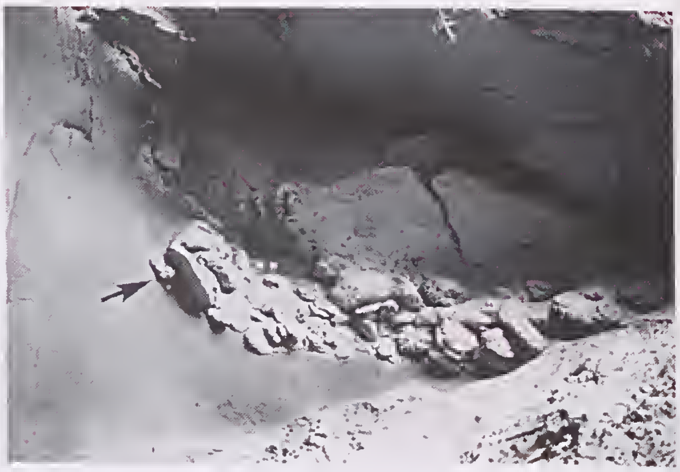


Figure 5. Fish Hook Bay wave-cut notch and storm beach deposit, elevation *ca.* 3.4 m above sea level. Feature consists of imbricated calcarenite cobbles emplaced in palaeosol. At upper left of cobble deposit is 15 cm scale. The arrow indicates the position of the dated *Turbo* shell.

Age estimation of the Fish Hook Bay palaeosol

Judging by its stratigraphic situation, the Fish Hook Bay palaeosol is potentially one of the oldest of these features on Rottnest. However, a radiocarbon sample of charcoal from the northernmost charcoal concentration (Fig 4a) gave an age of 18,660±250 yr b.p. (SUA 3030), which we consider to be erroneously young presumably as a result of contamination by younger carbonate. Although the sample was pre-treated to remove younger carbonate by boiling in dilute hydrochloric acid, because of its small size it was only lightly pre-treated by soaking in alkali-prophosphate to remove humic acids possibly present.

Radiocarbon age of the Fish Hook Bay storm beach deposit

Our interpretation of the wave-cut notch and storm beach deposit shown in Fig 5 as one of the many Rottnest shoreline features created by Middle Holocene high sea levels relative to the island's littoral and salt lake shorelines (Playford 1983, 1988, see below) is supported by a radiocarbon date of 5,730 ±60 yr B.P. (SUA 3037) for a whole *Turbo* shell from the storm beach deposit. A 1-2 m storm surge occurring when sea level was *ca.* 2 m above present level can easily account for the storm beach deposit's 3.4 m elevation.

Archaeological potential of shoreline and offshore zones

The oldest known Tamala Limestone on Rottnest island is exposed just at and below mean sea level at Fairbridge Bluff in Salmon Bay (Fig 1). Here, Tamala Limestone underlies the partly-emergent Rottnest limestone coral-reef unit (Playford 1988), dated by uranium- thorium technique to 132,000 ±5000 yr b.p. (Szabo 1979). This date suggests that the oldest Tamala Limestone shoreline features on the island, or submerged at shallow depths offshore, could pre-date the earliest human presence in this region. However, exposed at many places on Rottnest Island's mainly rocky shores are cemented soil horizons and sandy sediments that have infiltrated the cavities of solution pipes and other older limestone structures. At Little Armstrong Bay, for example, part of a palaeosol is exposed in an intertidal erosion pool. This palaeosol, which has in it rhizotubules and *Leptopius* weevil pupal cases, is intercalated between wave-eroded units of aeolian calcarenite. The lowermost palaeosol unit exposed at City of York Bay is approximately 1 m above sea level. These shoreline palaeosol units and sandy infillings are potentially places where isolated stone artifacts or other relevant finds could be located, both above and within the 2.4 m high inundation zone dating to the Middle Holocene transgression (see below).

Archaeological investigation of Rottnest Island rocky shorelines, including test excavation of unconsolidated sand filling the hollows of two large solution pipes just above sea level at the south-west end of Porpoise Bay, has not revealed any prehistoric material or terrestrial fossils (Figs 1B, 6). The partly excavated solution pipe illustrated rests on a 30-cm-thick reddish indurated palaeosol with rhizotubules, whose base is *ca.* 30 cm above sea level. The sediment excavated from these two pipes is a fine, iron-stained (reddish-yellow: 7.5YR 6/8) quartz sand similar to that of the Spearwood Dune System, which is one of the major constituents of the mainland Tamala Limestone (McArthur & Bettenay 1974), though not recorded on Rottnest Island. The presence on Rottnest of these sands is archaeologically significant, since some late Pleistocene to Middle Holocene assemblages of Eocene chert artifacts in the emergent Perth Basin are associated with Spearwood dunes, *e.g.* in the Pinnacles Desert 170 km north of Perth (Fig 1D; McNamara 1983), at Minim Cove near the mouth of the Swan Estuary (Fig 1; Clarke & Dortch 1977) and at Dunsborough (Ferguson 1982), as well as with dune soils on the western parts of the Leeuwin Block (Fig 1D) closely resembling and occupying the same sequential position as those of the Spearwood Dune System, *e.g.* at Quininup Brook (Ferguson 1981), Ellen Brook (Bindon & Dortch 1982), Devil's lair (Dortch 1984) and Arumvale (Dortch & McArthur 1985).

Figure 6. Partly excavated Tamala Limestone solution pipe, south-western end of Porpoise Bay, Rottnest Island, WA.

Playford (1988) notes that sub-aerial features, including aeolian calcarenite, palaeosols and limestone solution pipes, extend below sea level at many localities around Rottnest Island, probably reaching depths of 70 m or more. For example, there are a dozen solution pipes, 1.5 to 2.0 m high and 0.4 to 0.7 m wide, rising from the sea floor at depths of 3-5 m offshore Parker Point and Little Salmon Bay (Fig 1B). These Rottnest solution pipes closely resemble the one in Fig 7, photographed among a large number of submerged solution pipes surrounding a massive calcrete horizon in water 3 m deep near Little Island, two km offshore the mainland, and 25 km north-east of Rottnest Island (Fig 1). Although it is improbable that these features have much potential for archaeological survey, they are still part of a pre-transgression landscape traversed by human groups.

Figure 7. Submerged solution pipe in an outcrop of Tamala Limestone, near Little Island, offshore the Swan Region, W.A. (Photographed by Clay Bryce, WA Museum, Perth).

Discussion

Three factors are probably significant in accounting for Rottnest Island's extremely sparse prehistoric record.

1. The paucity of prehistoric finds may largely reflect late Pleistocene/Early Holocene occupation patterns in the Greater Swan Region. One of us (Dortch 1991) has proposed that the pre-transgression site distribution on the emergent, western half of the continental shelf was similar to that recorded in the present coastal plain (approximating the Perth metropolitan region). Here, Aboriginal occupation during the latter half of the Holocene, and probably during earlier millenia, was concentrated in the coastal plain's eastern, inland half, where abundant surface water and diverse resources are available (Hallam 1987). As suggested then, the outer, western part of the emergent shelf was not much used by prehistoric groups, and occupation instead was concentrated around wetlands and lakes in the shelf's inner parts, a likely example being the terminal Pleistocene - Early Holocene lagoon delineated by the 10 m contour in the central part of Cockburn Sound (Fig 1; Churchill 1959, Dept of Marine and Harbours 1988, Searle and Seminiuk 1985).

2. Middle Holocene high sea level (Thom and Chappell 1975), including sea level rise that reduced the newly formed island's area by more than a third following its

time of initial formation, and continued to rise, thereby inundating the newly formed island's low-lying areas, probably helps account for Rottnest Island's extremely sparse prehistoric record. This is because any intensive human occupation of the Rottnest locality shortly before its becoming an island is likely to have been concentrated at low elevation along marine shores, or in the vicinities of the island's swamps, which then would seem to have been fresh-water, judging by new evidence from Barker Swamp (Fig 1B) discussed below, or around the salt lakes, which perhaps also were brackish or fresh-water at that time.

Bathymetric contours of the sea floor between Rottnest Island and the mainland (Dept of Marine and Harbours 1988) imply that the post-glacial isthmus connecting the two was severed when rising seas reached a level 5-10 m below present mean sea level (see 10 m depth contour line in Fig. 1, and the 5 and 10 m contour lines in Fig 1A). Island formation with the sea at that level means that at its initial separation *ca.* 6500 years ago, Rottnest was forty per cent larger in area than it is now (Churchill 1959, Department of Marine and Harbours 1988). However, continuing sea level rise apparently within a few centuries inundated the newly formed island's shores, reaching a peak *ca.* 5900-4800 years ago, when sea level relative to the island is estimated to have been about 2.4 m higher than at present (Playford 1983, 1988). At that time, most of the present-day Rottnest shoreline was inundated, and the area of the island's salt lakes was a marine embayment sheltered from the open sea by stacks and islets (Fig lB). The evidence for these high sea levels relative to Rottnest Island consists of a number of radiocarbon-dated molluscan shell deposits located in modern quarry sites in the island's interior, or associated with wave-cut platforms and notches on the island's salt lake shorelines (Playford 1988). This record is now supplemented by the above noted 5700 yr b.p. elevated storm beach deposit emplaced in the Fish Hook Bay palaeosol (Fig 5). Although no archaeological features are associated with any of these elevated shoreline features and deposits, their presence may help to explain the dearth of Rottnest Island prehistoric sites. Playford (1988) has suggested that the Middle Holocene high sea levels relative to Rottnest Island may be more the result of localised tectonism than of glacio-eustatic sea level rise, continuing after sea level had reached its present height. Whatever its causes, inundation on this scale, preceded by the loss of more than a third of the newly formed island's area, has a destructive potential that cannot be ignored when assessing Rottnest Island prehistory.

3. Poor surface visibility must in part account for Rottnest Island's sparse prehistoric record, with most of the island's Tamala Limestone (including calcareous soil horizons and quartz residual dunes) covered by thick scrub or late Holocene dunes that restrict archaeological survey on the island to cliffs and other eroded Tamala Limestone features - particularly palaeosols, and to dune blow-outs and road cuttings. However, it is uncertain whether widespread exposure of subsurface features and ground surfaces on the island would reveal extensive or numerous prehistoric sites.

Prehistoric voyages to Rottnest Island?

Prehistoric Aboriginal voyages to Rottnest Island can be virtually discounted. For several Australian coastal regions there are ethnohistoric data relating to the seaworthiness of various kinds of Aboriginal watercraft. These data (Jones 1977) show that Rottnest is much too far offshore to have been within feasible voyaging range from the mainland. This is assuming that there was ever incentive to undertake a 19 km voyage to an offshore island in south-western Australia, a region for which there are plentiful ethnohistoric data for estuarine shoreline fishing (*e.g.* Moore 1978 [1884]), though where there is no indication of Aboriginal watercraft of any kind (Dortch & Morse 1984), and nothing to suggest prehistoric voyages to any offshore island, including Garden Island separated from the mainland by a 2 km-wide strait (Fig 1; Dortch & Morse 1984).

However, in considering possible prehistoric human visits to Rottnest following its formation, it is necessary to discuss the putative shell midden reported on the island by Hughes *et al.* (1978), which is a bed of marine mollusc shells (predominately *Turbo*, with a few limpets) on a low ledge near Parker Point (Fig 1B). This particular shell bed is considered to have accumulated through Pacific Gulls dropping shells in order to break them (Playford 1988), as observed on Rottnest Island by Teichert & Serventy (1947) and by Storr (1965). One of us has suggested that the shell bed is a storm beach deposit (Dortch 1991). We concur that the Parker Point shell bed probably is naturally accumulated, by one or perhaps by both of the processes noted above. Moreover, the low elevation of the deposit (1 to 3 m above sea level) places it within the range of the earlier noted Middle Holocene high sea levels that significantly eroded the island littoral. Therefore, this intact shell bed post-dates these high sea levels, and if it is a midden would presumably result from a human presence on the island following its formation. However, the weathered appearance of the shells in the upper part of the Parker Point deposit suggests to Hughes *et al.* (1978) that it is prehistoric rather than having "accumulated as a result of of shell gathering by Aboriginal convicts confined to the island late last century."

If the Parker Point deposit is a shell midden, it would be surprising that a deposit of this size, at least 100 times greater in mass than any of the 10 extremely small shell midden deposits recorded along south-western Australia's coastline - extending 1800 km from latitude 29° South to longitude 123° East (Dortch *et al.* 1984), would be found on a small, arid and relatively distant offshore island that otherwise has yielded absolutely minimal prehistoric remains of any kind (Table 1; *cf.* above comments on watercraft). The regional evidence for Aboriginal mollusc exploitation "is decidedly sparse and sometimes equivocal;" (Dortch *et al.* 1984), though this comment does not apply to the Parker Point shell deposit, which is prolific and almost certainly natural. (An archaeological examination of another Rottnest Island shell deposit resembling a midden has been made by Bindon *et al.* (1978).

Palaeoenvironmental considerations

During the last glacial maximum, with the sea at its lowest levels (Chappell & Shackleton 1986, Thom and Chappell 1975), Rottnest can reasonably be asumed to have been a waterless series of resource-poor limestone ridges and dunes. At that time, the only parts of Rottnest that may have been attractive for human groups are the present-day salt lakes (Fig 1B), which are probably karst structures (Playford 1988). Prior to sea level rise, these presumed caves or dolines could have featured rainwater pools.

Although the terrain on Rottnest and other parts of the outer shelf may have been uninviting during the glacial maximum, by the Early to early Middle Holocene, the shelf's still emergent parts would seem to have been suitable for human occupation, in part as a result of coastal plain water table rise consequent to glacio-eustatic sea level rise. These favourable conditions are suggested by radiocarbon dated biotic data from the mainland and from Rottnest Island. A pollen sequence for Loch McNess near the coast 50 km north of Perth (Fig1D) shows little change in local vegetation (mainly *Eucalyptus* woodland interspersed with swamp dominated by sedge communities) from 9000 yr b.p. until the present (Newsome & Pickett 1993). A corresponding record is provided by a radiocarbon dated sequence of peat, pollen, aquatic molluscs and ostracods (Backhouse 1993) from the lower part of a core at Barker Swamp, Rottnest Island, which shows that about 7,200 years ago and continuing for several centuries thereafter, this 1 ha swamp was an open freshwater lake surrounded by "sedges and *Callitris* [native pine] low forest, with a restricted jarrah / tuart [*Eucalyptus marginata/E. gomphocephala*] woodland present nearby" . The Barker Swamp record is to some extent supported by previous, much less well documented evidence consisting of the remains of a grass-tree (*Xanthorrhoea* sp.) radiocarbon dated *ca.* 7,000 yr b.p, and collected from a bore at an unknown locality on Rottnest Island (Churchill 1960). *Xanthorrhoea* is an understorey plant in jarrah and tuart woodland (Beard 1981), and remains of these species are also dated 7,000 yr b.p. in the Barker Swamp core (Backhouse 1993). Barker Swamp is is less than 1 m above sea level; its core record suggests that 7000 years ago, some or all of the island's other seven swamps were fresh-water bodies, as may have been the present-day salt lakes. This core record is evidence that the Rottnest area offered congenial conditions for human occupation for at least several centuries prior to its separation from the mainland.

The use of palynological and other palaeoenvironmental data, as well as submerged shelf topography and archaeological site distributions (Dortch 1991), in assessing former terrestrial environments and occupation patterns, as outlined here for the Greater Swan Region, has even greater applicability in those regions where the presence of numerous or extensive Pleistocene / Early Holocene archaeological sites on offshore islands or on mainland coasts leaves little doubt that the adjacent submerged shelf was an integral part of the landscape exploited by pre-transgression hunter-gatherer populations. In southern Australia (Fig 1C), these regions include Shark Bay (Bowdler 1990), the Archipelago of the Recherche (Dortch & Morse 1984), Kangaroo Island and neighbouring mainland peninsulas (Lampert 1981), and Bass Strait (*e.g.* Jones 1977).

Significance of the Rottnest prehistoric finds

The Rottnest Island prehistoric finds (Table 1) are all problematical, the two chert flakes because they were not found *in situ*, and the feldspar pebble because of its less than absolute cultural association. The calcrete flake (Fig 2:2) shows the archaeological potential of the Rottnest residual siliceous dunes; it is relevant that 117 limestone (mostly calcrete) artifacts were recovered from the late Pleistocene deposit at Devil's Lair cave (Fig 1D; Dortch 1984). The feldspar pebble (Fig 2: 3) and the two Eocene fossiliferous chert flakes (Fig 2:1, 4) clearly pre-date Rottnest Island's formation during the early Middle Holocene. The two flakes' presence on Rottnest island, like the two Eocene fossiliferous chert flakes from Garden Island and the many hundreds of others from the Archipelago of the Recherche (Fig 1C; Dortch & Morse 1984), is in keeping with their presumed age and derivation from chert outcrops on the emergent shelf.

These rare prehistoric finds to date imply that the pre-transgression land mass broadly synonymous with Rottnest Island was probably never occupied intensively. If such occupation did take place, the archaeological remains have been destroyed by Middle Holocene sea level rise and continuing marine conditions, or are buried beneath marine / lacustrine sediments, dune sands or some of the island's aeolian calcarenite units.

The potential of palaeosols within Tamala Limestone sequences on Rottnest Island for yielding rare archaeological finds is now apparent, and this potential may extend to palaeosol units in the Tamala Limestone throughout the Perth Basin and Leeuwin Block. The presence of what may be a single palaeosol unit extending for several km along Rottnest Island's northern shore offers perhaps the best opportunities for further prehistoric investigations on the island. The cultural finds described here and the estimated age of the palaeosols at the Little Armstrong Bay and City of York Bay find sites are suggestive of an age for prehistoric occupation in south-western Australia equalling or exceeding that shown for Devil's Lair - *ca.* 33,000 yr b.p. (Dortch 1984) and the Upper Swan site - *ca.* 38,000 yr b.p. (Pearce & Barbetti 1981). Further investigations on Rottnest should clarify the ages of some of these palaeosols, and verify the occurrence of prehistoric material within them.

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